Biogeochemistry of the greatest depths of the world ocean

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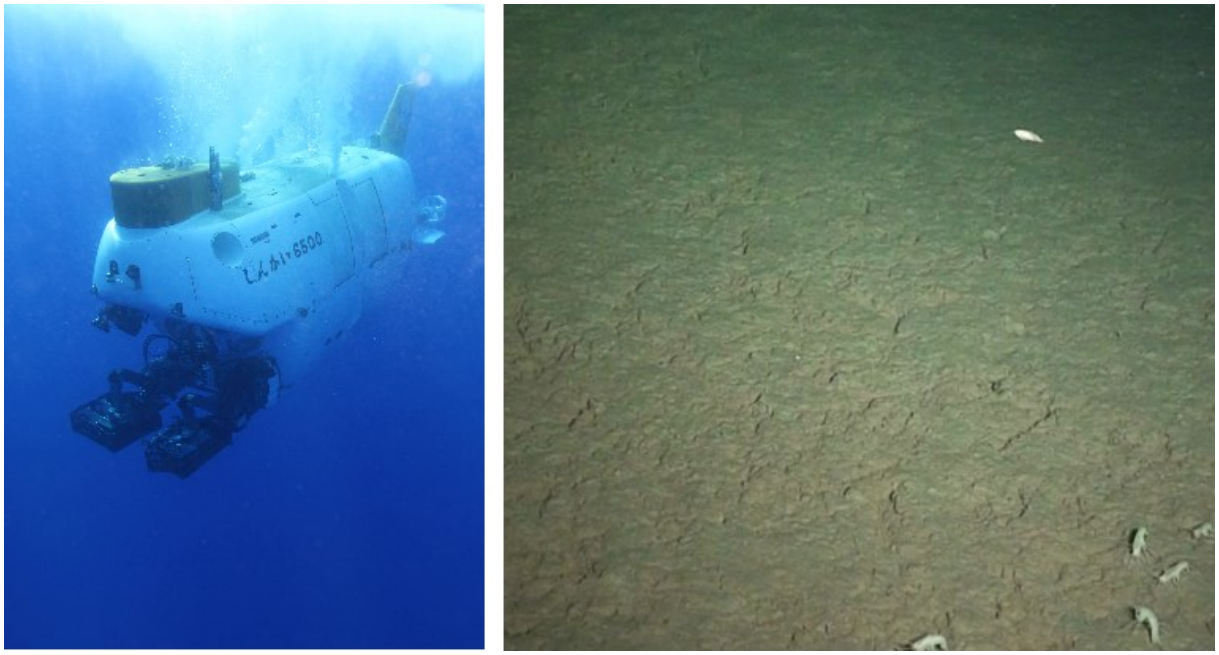
1. Background:

The deep sea is the largest ecosystem compartment of the global surface environment. This project aims to explore aspects of biogeochemical functioning in one of the most extreme parts of the deep sea – the so-called 'hadal' trenches. These trenches result from subduction of oceanic crust into the Earth's mantle and comprise water depths between 6000 m and almost 11000 m. In at least three respects, hadal trenches are an **extreme environment**. (a) Hadal trenches capture the uppermost ~45% of the hydrostatic pressure range in the ocean, with maximum pressures almost 1100 times higher than at the sea surface. However, very little is known about how carbon, nitrogen and other biogeochemically relevant elements are processed at these extreme pressures. (b) Hadal organisms are much further away from the food source in the photosynthetically active sunlit layers of the surface ocean than other deep-sea organisms. (c) Sloping seafloor in hadal trenches is associated with submarine 'landslides' (see figure) that are recurrent and more frequent than in other deep-sea settings. The role these mass-wasting events play for hadal biology and biogeochemistry is unknown.

Only recently, technological advances allowed for the first in situ investigations of biogeochemical processing to be carried out at the base of hadal trenches [1,2]. The studies revealed surprisingly high metabolic activity of the sedimentary microbial communities, even under very nutrient-poor surface-ocean waters. Given the three aforementioned extreme environmental properties, this counterintuitive result raises important questions about the biogeochemical functioning of hadal systems [3].



Left: on the way to collect samples at the rim of the Tonga Trench. Right: seafloor photograph of the trench axis in the Japan Trench, showing signs of sediment disturbance at a water depth of ~ 9200 meters [2].

2. **Key research questions:**

(a) Are microbial activities in hadal trenches surprisingly high BECAUSE OF or DESPITE the extreme environmental conditions?
(b) What is the relative importance of different food sources (pelagic-photoautotroph vs. benthic photoautotroph vs. terrestrial-photoautotroph vs. chemoautotroph)?
(c) Do hadal landslides reduce or enhance preservation or organic carbon in the seafloor?

3. **Methodology:** The PhD studentship project will be closely aligned with the ERC-funded HADES programme (Jan 2016 until Dec 2020). Two of the supervisors are directly involved in HADES (PI: R.N. Glud, University of Southern Denmark; Co-I: R. Turnewitsch, SAMS). A comprehensive set of sample material is already available from the KuramBio II cruise to the Kuril-Kamchatka Trench, leading to a considerable reduction of the risks that are inherent in any deep-sea projects. More sample material will be collected on a cruise in Jan/Feb 2017 to the Mariana Trench, and this material will be made available to the student when he/she starts in autumn 2017. Further opportunities for participation in research cruises and/or collection of more sample material are in autumn 2017 on a cruise to the Kermadec Trench, and in spring and autumn 2018 on cruises to the Atacama Trench. These trenches differ in their trench-axis depths, surface-ocean productivity, and distance to larger land masses, and they include settings with and without recent submarine mass-wasting, allowing for the key questions to be addressed. Samples will be analysed for key biogeochemical constituents and naturally occurring radioactive particle tracers. Organic-geochemical and stable-isotope analyses will provide information on composition, reactivity, quantity and provenance of organic matter. Analyses of naturally occurring particle-reactive radionuclides will inform about rates of transport of sediments and the constituent organic matter. There is also the possibility to carry out direct dating. Organic geochemical analyses will be carried out under the supervision of G. Cowie at the University of Edinburgh while analyses of particle tracers will be carried out under the supervision of R. Turnewitsch at SAMS. This combination of analyses will allow for a comprehensive investigation of sources and dynamics of organic material driving microbial activity in extreme hadal settings.

4. **Training:** A comprehensive training programme will be provided, comprising both specialist scientific training (relevant analytical techniques; ocean-going field work) and key transferable and professional skills. The project will help the student strengthen their ability to think and communicate across traditional discipline boundaries. Within the comparatively wide frame of this project the student will be able to develop their interests and independent thinking. Through connections to the HADES project and the German-Russian KuramBio II initiative, the student will benefit from an international, multidisciplinary and world-leading work environment, including the stimulating contacts to HADES-funded students who will work on microbiological and mineralisation aspects.

5. **Requirements:** For this project, the student would require a first-class chemical, biogeochemical or oceanographic background and a strong analytical mindset.

6. **Further reading:**

1 **Glud, R.N.**, F. Wenzhöfer, M. Middelboe, K. Oguri, **R. Turnewitsch**, D.E. Canfield, H. Kitazato, (2013). High rates of microbial carbon turnover in sediments in the deepest oceanic trench on Earth. *Nature Geoscience* 6, 284-288.

2 Wenzhöfer, F., Oguri, K., Middelboe, M., **Turnewitsch, R.**, Toyofuku, T., Kitazato, H., **Glud, R.N.** (2016). Benthic carbon mineralization in hadal trenches: Assessment by in situ O_2 microprofile measurements. *Deep-Sea Research I* 116, 276-286.

3 **Turnewitsch, R.** Falahat, S., Stehlikova, J., Oguri, K., **Glud, R.N.**, Middelboe, M., Kitazato, H., Wenzhöfer, F., Ando, K., Fujio, S., Yanagimoto, D. (2014). Recent sediment dynamics in hadal trenches: evidence for the influence of higher-frequency (tidal, near-inertial) fluid dynamics. *Deep-Sea Research I* 90, 125-138.

7. **Project summary:** This project aims to develop a comprehensive understanding of biogeochemical dynamics in hadal trenches – one of the most extreme parts of the marine environment that is only starting to be explored.